We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

Chapter

Nutritional Quality and Effect on Disease Prevention of Vegetables

João Silva Dias

Abstract

Vegetables have remarkable nutritional and health benefits. There are good reasons to include vegetables in human diet since they are enriched in bioactive compounds and by this reason they may help reduce the risk of some diseases. In this chapter, the nutrition quality and the effect on disease prevention of vegetables were analyzed. Each vegetable family and each vegetable contain a unique combination of bioactive compounds. The health benefit of vegetables should not be linked to one type of vegetable. Some experimental research evidences that vegetables exert antioxidative, anticarcinogenic, antidiabetic, and cardiovascular disease lowering effects are presented. The mechanism by which vegetable bioactive compounds decrease the risk of some of these diseases is complex and sometimes unknown.

Keywords: vegetables, health benefits, healthier life, nutrition, ANDI, bioactive compounds, antioxidants, dietary fiber, vitamins, minerals, phytochemicals

1. Introduction

Vegetables are important for nutritional balanced diets since they supply bioactive compounds such as dietary fiber, vitamins, minerals, and phytochemicals [1–3]. They are also associated with disease prevention by improvement of gastrointestinal health, good vision, and reduced risk of chronic and degenerative diseases such as cardiovascular diseases, certain cancers, diabetes, rheumatoid arthritis, and obesity [3–8].

In recent years consumers began to be more aware of the relation of eating patterns with nutrition and human disease prevention, and there is a general agreement among scientists, nutritionists, and dieticians that the promotion of a greater consumption of vegetables will improve nutrition quality and will bring health benefits.

The mechanisms by which vegetable consumption prevents diseases have not yet been fully understood [2, 3]. However, scientists, nutritionists, and dieticians believe that the bioactive compounds such as dietary fiber, vitamins, minerals, and phytochemical contents are responsible for mitigating some human diseases. All these different compounds may contribute to the overall health benefit. So, the health benefit of vegetables should not be linked to only one bioactive compound or one type of vegetable, but rather with a balanced diet that includes more than one type of vegetable [1–3].

Some vegetable phytochemicals (glucosinolates, thiosulfates, polyphenols, bioactive peptides, etc.) have positive effects on health. They are strong antioxidants, and they reduce the risk of chronic diseases by protecting against free radical damage, by modifying metabolic activation and detoxification of carcinogens, or even by influencing mechanisms that alter the course of tumor cells [1–3]. Phytochemicals are the key to better health as well as disease prevention.

All vegetables are sources of important vitamins (C, A, B1, B6, B9, E) and minerals and consequently have nutritional and health benefits [2, 3].

Dietary fiber is a major constituent of vegetables. Dietary fiber and other bioactive molecule contents have been usually addressed separately in nutritional studies. However, vegetable dietary fiber transports, through the human gut, a significant amount of phytochemicals, vitamins, and minerals linked to the fiber matrix [9, 10]. Therefore, associated phytochemicals, vitamins, and minerals of the whole aliment may contribute to the overall health benefit usually attributed to the dietary fiber of vegetables [2, 3].

The objective of this paper is to explore the nutritional quality and effect on disease prevention of vegetables.

2. Nutritional quality of vegetables

2.1 Vegetables

From more than 1000 plants that are used as vegetables, Kays and Dias [11, 12], based on a world survey, report that at least 402 vegetables are cultivated and commercialized worldwide. They represent 69 families and 230 genera. From these great diversity, leafy and stalk vegetable group comprised 53% of the total, followed by fruit and flower vegetable group (15%) and belowground (root, bulb, and tuber) vegetable group (17%). Many of these vegetable crops have more than one part used.

Leafy and stalk vegetable group include lettuce, chicory, coles (head cabbages, kales, tronchudas, collards, Brussels sprouts, etc.), Chinese cabbage, pak-choi, turnip greens, mustards, rocket, watercress, Swiss chard, spinach, purslane, New Zealand spinach, celery, asparagus, rhubarb, fennel, chives, parsley, coriander, etc.

Fruit and flower vegetable group include tomato, pepper, eggplant, watermelon, melon, cucumber, squash, pumpkin, zucchini, bitter gourd, peas, beans, lentils, okra, sweet maize, cauliflower, broccoli, kailan, broccoletti, artichoke, etc.

Root, bulb, and tuber vegetable group include carrot, garden beet, turnip, radish, rutabaga, parsnip, sweet potato, cassava, celeriac, onion, garlic, shallot, leek, Welsh onion, potato, etc.

2.2 Vegetables and human nutrition

Until few years ago, it was believed that the key for human nutrition and health was only 14 vitamins and 16 essential minerals. Recently, with the great developments in chemistry, it was found that, in addition to these vitamins and minerals, vegetables contain thousands of beneficial phytochemicals. As mentioned some vegetable's phytochemicals are robust antioxidants and are believed to reduce the risk of some chronic and degenerative diseases [2–4].

With the exclusion of the organosulfur compounds (OSCs) glucosinolates and thiosulfates (which are distinct phytochemicals of Brassicaceae and Alliaceae families, respectively), the phytochemical, vitamin, and mineral contents of many vegetables lie principally in dietary fiber, polyphenols (carotenoids, flavonoids), vitamin C, folate, calcium, and selenium [2, 3]. The principal dissimilarity is that each vegetable family incorporates a distinct amalgam and amount of these bioactive compounds, which differentiate them from other vegetables [2, 13].

Vegetables of the Apiaceae family (carrot, parsnip, celery, celeriac, fennel, parsley, coriander, etc.) are rich in flavonoids, carotenoids, vitamin C, and vitamin E. For example, celery and parsley are among the best vegetable sources for the flavonoid apigenin and vitamin E [2, 14], and carrots have a unique combination of three flavonoids: kaempferol, quercetin, and luteolin [15–17].

Vegetables of the Asteraceae or Compositae family (lettuce, endive and escarole chicories, stem lettuce, globe artichoke, etc.) are rich in flavonoids, tocopherols, and conjugated quercetin. Crozier et al. [18] observed sizeable variations in flavonol content within lettuce cultivars. The outer leaves of "Lollo Rosso," a red cultivar, contained 911 μg/g fresh weight of quercetin, in contrast with the common head lettuce that contained only 11 μg/g. And, the levels in iceberg lettuce were even lower than in the head lettuce. The red color of "Lollo Rosso" lettuce is due to high levels of anthocyanins, which like quercetin are products of the phenylpropanoid pathway. As one end product of the pathway has been elevated, it may well be that other related compounds, including the flavonols, are also found in higher concentrations. Roman lettuce is richer in lutein than head lettuces; and leafy and roman lettuces are richer in quercetin [3, 13].

The Chenopodiaceae family vegetables (Swiss chard, spinach, garden beet, quinoa, etc.) are among those that are rich in oxalates [19, 20] but also excellent sources of dietary fiber, vitamins, calcium, manganese, flavonoids, and carotenoids. When oxalates become too concentrated in body fluids, they can crystallize and cause health problems such as kidney calcium oxalate stones.

The Cucurbitaceae family vegetables (e.g., squash, pumpkin, cucumber, melon, bitter gourd, etc.) are rich in carotenoids, and tocopherols, and vitamin C [21]. Burger et al. [22] in a survey of 350 melon accessions observed a 50-fold variation in ascorbic acid content, ranging from 0.7 to 35.3 mg/100 g fresh weight. Ascorbic acid and β-carotene content ranged from 7.0 to 32.0 mg/100 g and 4.7 to 62.2 μg/100 g, respectively, in sweet melons [23].

The vegetables of the Leguminosae or Fabaceae family (all the legumes, e.g., pea, bean, soybean, lentils, chickpea, etc.), mature and immature seeds, are great sources of dietary fiber, resistant starch, protein, isoflavonoids [24], calcium, and iron. Mallillin et al. [25] studied the total, soluble, and insoluble fiber and fermentability characteristics of 10 legume mature seeds (mung bean, soybean, peanut, pole sitao, cowpea, chickpea, green pea, lima bean, kidney bean, and pigeon pea). They concluded that the dietary fiber content in these ten legumes ranged from 20.9 to 46.9 g/100 g and that the best sources after in vitro fermentation using human fecal inoculum-stimulating conditions in the human colon (as mmol/g/fiber isolate of acetate, propionate, and butyrate produced after fiber fermentation) were pole sitao and mung bean (acetate), kidney bean and pigeon pea (propionate), and peanut and cowpea (butyrate). High-flavonol legumes include sugar snap peas and mange tout, which were found to contain 98 and 145 μg quercetin/g, respectively [2]. As mentioned some legumes are also rich in iron. Trinidad et al. [26] studied the mineral availability in vitro of iron, zinc, and calcium in 10 local legumes (cowpeas, mung beans, pole sitao, chickpeas, green peas, groundnuts, pigeon peas, kidney beans, lima beans, and soybeans). They found that the highest iron availability among these legumes was for lima beans and mung bean, while for zinc and calcium, the highest availability was for kidney beans and pigeon peas. Groundnuts have the lowest iron, zinc, and calcium availability. They concluded that mineral availability of iron, zinc, and calcium from legumes differs and may be attributed to their mineral content, mineral-mineral interaction, and their phytic and tannic acid content. Mung bean either eaten as whole pod grains or grown to produce bean sprouts is an important source of iron for women and children throughout South Asia [1, 27].

Vegetables of the Brassicaceae or Cruciferae family, which include kales, collards, cabbages, Brussels sprouts, cauliflower, broccoli, kailan, pak-choi, Chinese cabbage, turnip, broccoletti, swede, watercress, radish, horseradish, rocket, mustards, etc., are high sources of glucosinolates, as well as vitamin C, carotenoids, folates, and calcium, and can accumulate selenium. Comparative studies of glucosinolate profiles within each Cruciferae, and among accessions and plant parts, indicate significant quantitative and qualitative differences [28–39]. Kushad et al. [34] observed in 65 broccoli cultivars that glucoraphanin was the predominant glucosinolate and that there was more than 27-fold difference between the highest concentration in "Brigadier" and the lowest in "EV6–1." Hansen et al. [40] also observed in 21 red cabbage and 6 white cabbage cultivars, a considerable variation in the concentration of glucosinolates. Red cabbages were found to contain significantly higher concentrations of glucoraphanin compared to white ones. There were also significant differences within the red cabbages examined: "Rodima" had the highest level of glucoraphanin (7.4 mg/g), whereas "Primero" has the lowest (0.6 mg/g). The white cabbages presented significantly higher levels of glucoiberin than the red ones: white cabbage "Bartolo" had the highest concentration of glucoiberin (7.4 mg/g), whereas "Candela" has the lowest (1.7 mg/g), and red cabbages ranged from 3 to 0.3 mg/g. The red cabbages were also found to contain significantly higher levels of gluconasturtiin than white: "Amager Garo" had the highest level of gluconasturtiin (1 mg/g), whereas "Primero" had the lowest (0.1 mg/g). In turnip and rutabagas, similar differences between accessions were also observed [30]. Fahey et al. [41] evaluated glucosinolate content of broccoli sprouts and found that they contain nearly 20- to 50-fold higher glucosinolate concentrations than tissue from mature plants. In broccoli heads, the predominant glucosinolates are glucoraphanin, glucobrassicin, progoitrin, and gluconasturtiin [32, 34, 36, 38, 42, 43]. In cabbage, Brussels sprouts, cauliflower, kale, tronchuda, and collard, the most significant glucosinolates are sinigrin, progoitrin, and glucobrassicin [29, 32, 34, 39, 40, 44]. In turnip and rutabagas, the major glucosinolates are glucoerucin, glucoraphanin, and glucobrassicin [30, 33]. In radish, the most significant glucosinolates are glucoerucin, glucoraphanin, and glucobrassicin [31, 35]. Each of these Cruciferae also contains smaller amounts of other glucosinolates.

Cao et al. [45] observed that in Brassicaceae vegetables vitamin C is the most abundant vitamin in coles (cabbage, broccoli, cauliflower, Brussels sprouts, tronchuda, and kale) and that kale rated as the second highest vitamin content and the second highest among 22 vegetables. They are also excellent sources of folate. Brussels sprouts and broccoli rank among the highest vegetable sources for folate [46, 47]. Most of the Cruciferae are also good sources of calcium. Kales, tronchudas, and collards contain the highest content in fiber and calcium when compared to other Brassicaceae. Vegetables of the Cruciferae family are able to accumulate selenium when grown on selenium-enriched soils. Banuelos and Meek [48] stated that broccoli-grown soils with high-selenium levels accumulated sevenfold more selenium than cabbage, collards, and Swiss chard.

Vegetables of the Alliaceae family (e.g., onions, garlic, shallots, leek, Welsh onion, chives, etc.) are rich in thiosulfates, flavonoids, calcium, potassium, manganese, and chromium and can accumulate selenium. The types and composition of thiosulfates differ from *Allium* [49]. Kalra et al. [50] reported that garlic fresh bulbs contain 33 thiosulfates. The major thiosulfates in the cytoplasm of *Allium* species are S-allyl-cysteine sulfoxide (alliin), S-methyl-cysteine sulfoxide (methiin), and γ-glutamyl-L-cysteine [51]. Other minor thiosulfates include S-propenyl-cysteine sulfoxide (isoalliin) and S-ethyl-cysteine (ethiin) [52]. None of the thiosulfates found in *Allium* have been detected in other vegetables, except S-methyl-cysteine sulfoxide (methiin) which was detected in some Cruciferae [53]. The most important thiosulfates detected in onion bulbs are isoalliin (49%), methiin (34%), propiin (6%), ethiin (5%), and alliin (5%) and in garlic alliin (92%) and methiin (8%) and trace amounts of ethiin, propiin, and isoalliin [51, 53–55].

The second most important group of bioactive compounds in *Allium* is flavonoids. Miean and Mohamed [56] mentioned that onion leaves had the highest total flavonoid content among 62 different vegetables. About 55% of this total of flavonoids is quercetin, 31% kaempferol, and 14% luteolin. Two flavonoids are found in onion bulbs: anthocyanins in red onions and flavonols like quercetin (more than 95%) and kaempferol in most yellow onion varieties [57]. White onion cultivars have significantly less quercetin than the red ones [2, 3, 58]. In garlic cloves, 72% of the total flavonoids is myricetin, 23% apigenin, and 5% quercetin [56]. In chive, garlic chive, and leek, the predominant flavonoid is kaempferol [58].

Onion and garlic are excellent sources of calcium, potassium, and manganese providing up to 10% of the human daily requirements. Most of the onions and garlics contain very low concentrations of selenium but can accumulate selenium when grown on selenium-enriched soils. Ip and Lisk [59] reported that garlic fertilized with a high selenium and low sulfur fertilizer accumulated between 110 and 150 ppm selenium, while onion accumulated up to 28 ppm. Onions also contain chromium [2]. Two hundred grams of onions contain up to 20% of the daily requirements in chromium. Onions are a rich source of dietary fibers and especially of inulin, a polyfructosan, that has prebiotic properties [2, 3].

Vegetables of the Solanaceae family that includes tomato, potato, sweet and hot peppers, eggplant, etc. are very diverse, in their contribution to bioactive compounds.

Tomato is the second most produced and consumed vegetable in the world after potato. Tomato has a unique nutritional and phytochemical profile. Carotenoids are the major bioactive compounds in tomato with 60–64% lycopene, 10–12% phytoene, 7–9% neurosporene, and 10–15% carotenes [60]. Red varieties of tomato contain more lycopene (on average 90 mg/kg) than yellow ones (5 mg/kg) [61]. The average daily intake of lycopene in human diet is about 25 mg/day. Processed tomatoes (juice, sauce, paste, and ketchup) contain higher lycopene (2- to 40-fold) than fresh tomatoes [60, 62, 63]. Lycopene is a very potent antioxidant [64, 65].

Tomato contains also significant amounts of α-, β-, γ-, and δ-carotene (0.6–2.0 mg/kg) which make it for consumers a top contributor of provitamin A and vitamin A [66, 67]. Tomatoes are also an excellent source of vitamin C [68]. Tomato contains small amounts of lutein, α-, β-, and γ-tocopherols and conjugated flavonoids (quercetin and kaempferol) [66, 69–71]. About 98% of these flavonoids are present in the peel [72]. Cherry tomato cultivars have higher flavonoid contents than beef ones, and field-grown tomatoes have higher flavonoid contents than greenhouse-grown ones [18, 72]. Tomatoes are also an excellent source of potassium.

Potato is usually only associated as a source of carbohydrates. But it is also an excellent source of essential amino acids (such as lysine) and other bioactive compounds [2]. In addition to superior quality proteins, potato tubers also have significant amounts of vitamins and minerals, as well as phytochemicals (phenolics, phytoalexins, etc.), and protease inhibitors [73, 74]. There are yellow-, red-, and purple-fleshed potato cultivars with high content of phytochemicals; nevertheless, some cultivars are known to have lower [2]. Other bioactive antioxidants presented in potato tubers include α-tocopherol, lutein, β-carotene, folates, and selenium [73, 74].

Peppers are excellent sources of vitamins C, K, carotenoids, and flavonoids [75]. They provide also a respectable amount of dietary fiber. Peppers contain in average 1–2 g/kg of vitamin C, which is equivalent to 200–300% of the recommended daily allowance [76]. Their content of provitamin A carotenoids (α- and β-carotene) depends in the cultivar. Some cultivars of hot pepper have 12 mg/kg total carotenoids, while others have trace amounts [76, 77]. In pepper, the major conjugated flavonoids are quercetin and luteolin. Their content varies among cultivars ranging from not detectable to 800 mg/kg [78]. Red bell peppers have significantly higher levels of bioactive compounds than green ones. Red bell peppers also contain lycopene [74].

In hot peppers or chilies, the major phytochemicals are capsaicinoids [2, 74]. More than 20 capsaicinoids, belonging to capsaicin and dihydrocapsaicin groups, have been identified. Capsaicin contributes about 70% for the pungent/hot fire flavor in chili peppers, while dihydrocapsaicin represents 30% [79]. Significant variations in capsaicinoids are found between and within peppers, ranging from about 220 ppm in *Capsicum annum* (sweet pepper) to 20,000 ppm in Capsicum chinense (hot pepper) [80]. Fresh chili peppers have high levels of vitamins and minerals. Just 100 g of hot peppers, red or green, provides 240% of vitamin C, 39% of vitamin B6-complex group, 32% of vitamin A, 13% of iron, 14% of copper, and 7% of potassium of the recommended daily allowance [81]. Chili peppers contain a good amount of manganese and magnesium [2].

Eggplant besides vitamins (C, K, B6-complex group, folate, and niacin) and minerals (magnesium, copper, manganese, molybdenum, potassium) also contains important phytochemicals like flavonoids, such as nasunin, and phenolic compounds, such caffeic and chlorogenic acid [2, 74]. Nasunin is the major phytochemical in purple eggplant cultivars. Nasunin is part of the anthocyanin purple pigment found in the skin of eggplant [82–84]. Matsuzoe et al. [85] examined the profile of anthocyanins in several eggplants and found that nasunin represents between 70 and 90% of the total anthocyanins in the skin. Nasunin is an antioxidant that effectively scavenges reactive oxygen species, such as hydrogen peroxide, hydroxyl, and superoxide, as well as inhibits the formation of hydroxyl radicals, probably by chelating ferrous ions in the Fenton reaction [82, 84]. The predominant phenolic compound found in all cultivars of eggplant tested by Matsuzoe et al. [85] is chlorogenic acid, which is one of the most potent free radical scavengers found in plant tissues. Benefits attributed to chlorogenic acid include antimutagenic (anticancer), antimicrobial, and anti-low-density lipoproteins and antiviral activities. In addition to chlorogenic acid, Whitaker and Stommel [86] found 13 other phenolic acids present in seven eggplant cultivars. "Black Magic" was found by these authors to have nearly three times the amount of antioxidant phenolics as the other eggplant cultivars studied. Eggplant fruits also contain several other antioxidants including flavonoids myricetin and kaempferol as well as carotenoids lycopene, lutein, and α-carotene [56, 87]. Eggplant is richer in nicotine than any other edible vegetable and contains measurable amounts of oxalates [2, 74]. Due to oxalates individuals with already existing and untreated kidney or gallbladder problems may avoid eating eggplant [74, 88].

Looking generally for the nutrition quality of vegetables groups we can say. In the leafy and stalk vegetables, they are fiber sources, rich in important minerals such as calcium, magnesium, and iron and vitamins C and A and riboflavin. In this group, young fresh leaves contain more vitamin C than mature plants. The thinner and greener leaves are more nutritious respecting vitamins and minerals but less nutritious respecting dietary fiber. The green outer leaves of the head or pseudo-head leafy vegetables such as cabbage, lettuce, and endive chicory are usually richer in calcium, magnesium, iron, and vitamins than the inner leaves. Stalk vegetables like tronchuda cabbage, pak-choi, celery, and asparagus are rich in dietary fiber.

In the fruit and belowground organ vegetables, the skin and inside color reflect different bioactive compounds/pigment present. Anthocyanins (flavonoid) give vegetable leaves, belowground organs, and fruits their purple and purple-red color appearance, such as in red anthocyanin lettuce and endive chicory, red cabbage, Swiss chard, rhubarb, etc. (leafy and stalk vegetables); garden beet, purple carrot, red onion, purple- and purple-red-skinned potato, purple sweet potato, etc. (below ground vegetables); and purple eggplant, purple tomato, purple pepper, purple and black broccoli, purple corn, etc. (fruit and flowering vegetables). The most abundant carotenoids in vegetables are α-carotene, β-carotene, and lycopene (carotenes) and lutein, zeaxanthin, and β-cryptoxanthin (xanthophylls) [2, 74, 89]. The most common carotenes are β-carotene and lycopene. β-Carotene (as well as α-carotene) can be found in orange and yellow skin fruits, belowground organs, and leafy vegetables [2, 74]. As a rule of thumb, the greater the intensity of the orange color, the more β-carotene the vegetable contains [2, 74]. Lycopene can be found in red fruits (e.g., tomato), red belowground organs (e.g., red carrot), and red leafy vegetables. Lutein is the most abundant xanthophyll [2, 74]. Xanthophylls are responsible for the yellow color of vegetables.

2.3 ANDI and nutritional quality of vegetables

Aggregate Nutrient Density Index (ANDI) is a scoring system based on nutrient content, rated on a 1–1000 scale that was established by Fuhrman [90]. This index are scores attributed to a variety of vegetables (and other foods) based on how many nutrients they deliver to our body in each calorie consumed. It was calculated by evaluating the content of dietary fiber, vitamins, minerals, phytochemicals, antioxidant capacities, etc. It is an index that estimates the nutritional quality of vegetables. **Table 1** presents the highest ANDI scores in leafy vegetables.

Three main vegetable families are shown in this table: Brassicaceae (kale, collard greens, mustard greens, turnip greens, watercress, pak-choi, Chinese cabbage, Brussels sprouts, rocket, cabbage and broccoletti), Chenopodiaceae (Swiss chard and spinach), and Asteraceae (green leaf lettuce, chicory, and romaine lettuce). The highest ANDI scores of non-leafy vegetables are presented in **Table 2**.

Table 2 also shows other Brassicaceae like radish, turnip, kohlrabi, cauliflower, and rutabaga. Different vegetables from various families are also shown as well as differences among the peppers, where orange pepper is better than the red and red better than the green pepper.

Leafy vegetables thus have the highest ANDI scores compared to other vegetables. They are rich in dietary fiber, carotenoids, vitamin C, vitamin E, flavonoids, calcium, magnesium, etc. All the leafy vegetables are good sources of magnesium because they have chlorophyll.

The leafy vegetables with high ANDI scores are Brassicaceae. They have dietary fiber, are a rich source of glucosinolates and other bioactive nutrients, and have a

Vegetable	ANDI	Vegetable	ANDI
1.Kale	1000	9.Chinese cabbage	714
2.Collard greens	1000	10.Brussels sprouts	672
3.Mustard greens	1000	11.Rocket	604
4.Swiss chard	1000	12.Lettuce (green leaf)	585
5.Turnip greens	1000	13.Chicory	516
6.Watercress	1000	14.Romaine lettuce	510
7.Pak-choi	865	15.Cabbage	481
8.Spinach	739	16.Broccoletti	455

Table 1.
List of identified leafy vegetables with the highest ANDI scores.

Vegetable	ANDI	Vegetable	ANDI
1.Radish	502	7.Cauliflower	315
2.Turnip	473	8.Rutabaga	296
3.Carrots	458	9.Bell pepper (red)	265
4.Winter squash “Acorn”	444	10.Bell pepper (green)	258
5.Bell pepper (yellow/orange)	371	11.Artichoke	244
6.Kohlrabi	352	12.Asparagus	234

Table 2.
List of identified non-leafy vegetables with the highest ANDI scores.

very high content in calcium and β-carotene. They are excellent sources of lutein and can also accumulate selenium.

Another important family is Chenopodiaceae. A recent research has shown that Swiss chard leaves contain at least distinct polyphenol antioxidants [91] comprising the flavonoids kaempferol and syringic acid [91–93]. Swiss chard and garden beet leaves have a unique source of the bioactive antioxidants named betalains [2, 74]. Nine betacyanin pigments were identified in the reddish-purple stems and veins of the leaves of Swiss chard and beet [94]. In the Swiss chard’s yellowish stems and veins, 19 betaxanthin pigments were identified, including histamine-betaxanthin, alanine-betaxanthin, tyramine-betaxanthin, and 3-methoxytyramine-betaxanthin [94].

In Asteraceae, lettuces and chicories are the main vegetables used in raw salads. Leaf and romaine lettuces have higher ANDI scores (585 and 510, respectively) than iceberg lettuce. Besides, the nutritive value of leaf and romaine lettuce is higher than head lettuces (butter and batavia types). They have more dietary fiber, minerals, vitamins, and phytochemicals. Raw vegetables are the healthiest food we can eat since some phytochemicals are only available if we eat the vegetables raw [95].

In the non-leafy vegetables, we have after radish and turnip (both Brassicaceae) the carrots. They are high in fiber and nutrient rich. Carrots have different colors. Orange carrots have α- and β-carotene (vitamin A-rich carotenoids), and purple carrots are rich in anthocyanins (flavonoids) and low in carotenoids [96, 97]. Winter squash “Acorn” has a high β-carotene content. Kohlrabi, cauliflower, and rutabaga are also Brassicaceae, and so they are good sources of vitamins, minerals, and healthy glucosinolates. Kohlrabi (stem) and rutabaga (roots) besides having high vitamin C and antioxidant content due to glucosinolates are good alternative to potatoes since they are not starchy as potato and can be eaten raw and when sliced they do not produce discoloration. The nutritional value of the outer leaves of cauliflower is much higher than the flower buds. Artichoke is rich in fiber and a good source of minerals, namely, calcium, potassium, and phosphorus. It contains also many bioactive compounds such as glycosides and phenolics, mainly caffeicinic acid [98]. Asparagus besides rich in fiber is a very rich source of folic acid.

3. Effect on disease prevention of vegetables

3.1 Effect on cancers

The International Agency for Research on Cancer (IARC) estimates that the percentage of cancers due to unbalanced diets with low vegetable intake and low consumption of complex carbohydrates and dietary fiber ranges from 5 to 12% for all cancers and 20–30% for upper gastrointestinal tract cancers [2, 3]. The World Health Organization (WHO) states that about 14% of worldwide deaths are attributable to gastrointestinal cancers due to inadequate vegetable and fruit consumption [99]. The American Cancer Society observed that more than two-thirds of cancer deaths in the United States are avoidable and reported that one-third of cancer deaths can be prevented by a proper diet rich in vegetables [100, 101].

Numerous epidemiological studies conducted in the United States and in developed countries, which include results from tests on adenomatous polyps (the precursors to colorectal cancer), concluded that high vegetable intake decreases the risk of colorectal cancer [26, 102–106]. Witte et al. [107] observed significantly lower incidence of colorectal polyps in men and women ages between 50 and 74 years old who consumed higher rates of vegetables, namely, crucifers, garlic, and tofu. It is also interesting also that this research concluded that vegetables have more beneficial effects against colorectal polyps than fruits or fiber from grains. In another research with 41,837 women aged between 55 and 69 years old, Steinmetz et al. [106] found a 20–40% reduction in risk of colon cancer in populations with higher vegetable consumption. Other studies have also estimated lower risk of colon cancer, ranging from three- to eightfold due to high vegetable and fruit intake [26, 108–110]. Increasing the consumption of vegetables reduces the risk of cancer since the antioxidants in vegetables prevent the oxidative damage of the cells in the body [111, 112]

Leafy vegetables have protective effects against cancers, especially gastrointestinal carcinomas, mainly due to dietary fiber, but also to phytochemicals, vitamins (C, E, K, and A), and minerals they contain [113]. Tewani et al. [114] state that spinach shows protective effects against gastrointestinal cancer by reducing oxidative stress thanks to vitamins (C and E), carotenes (mainly β-carotene), lutein, and flavonoids (mainly flavones) it contains.

Cruciferous vegetables rich in glucosinolates have been shown to protect against lung cancer, prostate cancer, breast cancer, and chemically induced cancers [115–119]. The evidence concerning the anticarcinogenic effect of glucosinolates of cruciferous vegetables were from in vivo studies, mainly with broccoli, using animal models and human volunteers [116, 118–124].

Intact glucosinolates have no biological activity against cancer. However, their breakdown products have been shown to stimulate mixed-function oxidases involved in detoxification of carcinogens, reducing the risk of certain cancers [28, 125, 126]. Not all glucosinolate breakdown products have anticancer activity [127]. The glucosinolates glucoraphanin, glucoiberin, glucobrassicin, and gluconasturtiin are involved in the anticarcinogenic activity, and glucoraphanin is known to bolster the defenses of cells against carcinogens through an upregulation of enzymes of carcinogen defense.

Epidemiological data show that a diet rich in cruciferous vegetables can reduce the risk from several cancers by an intake of at least 10 g per day [115, 116, 118]. Epidemiological studies have suggested that diets rich in broccoli may reduce the risk of prostate cancer, and consumption of one or more portions of broccoli per week can reduce the incidence and the progression from localized to aggressive forms of prostate cancer [118, 119]. There is also strong evidence that isothiocyanates (an important group of breakdown products of glucosinolates) from cruciferous vegetables prevent bladder cancer, namely, transitional cell carcinoma of the urinary bladder [128].

Consumption of *Allium* vegetables has been also found to retard growth of several types of cancers. A number of epidemiological studies show inverse correlations between the consumption of *Allium* vegetables, mainly onions and garlics, and the reduced incidence of cancers.

There is a strong link between the consumption of onions and the reduced incidence of stomach and intestine cancers [129, 130]. Control studies reveal that consumption of one to seven portions of onions per week reduces the risks of colon, ovary, larynx, and mouth cancers [131]. Mortality due to prostate cancer also appears to be reduced by a diet making a large consumption of onions [132]. Onion extracts prevent tumors by inhibiting the mutation process [133] and reducing the proliferation of cancer cells [134].

Epidemiological researches show the correlation between moderate garlic intake and a low esophageal and stomach tract cancer incidence [131, 135, 136]. Garlic extracts prevent tumor initiation by inhibiting the activation of pro-carcinogens and by stimulating their elimination [137, 138]. A regular consumption of garlic has been associated also with the reduction in the incidence of preneoplastic lesions occurring in the gastric mucosa of individuals infected by *Helicobacter pylori* [139]. Other studies analyzing the preventive effect of garlic have evidenced their suppressive potential on the development and progression of colorectal adenomas [110, 140]. A reduced cancer risk by regular consumption of garlic has been widely documented also for colorectal and prostate cancers [131, 136, 141, 142]. The impact of a diet rich in *Allium* vegetables in antiprostate cancer is higher in men presenting localized rather than advanced forms [142].

The impact of a regular intake of *Allium* vegetables on the incidence of cancers affecting the breast, endometrium, and lungs has been studied in a limited number of investigations [143–145]. The risk of breast cancer was shown to decrease as consumption of *Allium* increased [143]. Onion extracts have apoptosis-inducing effects in epithelial MDA-MB-231 cells that cause breast cancer [146].

In tomato several investigations have shown an inverse relationship between plasma/serum lycopene concentrations and the risk of some cancers [147–153]. Reports on 13 cancer types were identified in literature, of which breast, colorectal, gastric-gastrointestinal, and prostate cancers. For breast, colorectal, and gastric cancers, the existing data support a potential protective association between tomato and lycopene intake and cancer risk. People consuming diets rich in tomato/lycopene and tomato-based products were found to be less likely to develop stomach and rectal cancers than those who consume lesser amounts [154]. Among the cancers investigated, prostate cancer is the most widely researched. Tomato and lycopene intake is preventive against prostate cancer [13, 155]. Hadley et al. [156] in an epidemiological study found that consuming tomato and tomato products was associated with a lower incidence of prostate cancer [156]. A prostate cancer risk reduction of nearly 35% was observed when the test subjects consumed 10 or more servings of tomato per week [157]; and the effect was much stronger for patients with more aggressive and advanced stages of cancer [157].

Other Solanaceae associated with cancer prevention are chili peppers and eggplant. Chili peppers are tough to prevent cancer cells from growing, developing, and spreading due to it capsaicin content [158]. A study of Nagase et al. [159] showed that eggplant extract inhibited human fibrosarcoma HT-180 cell invasiveness.

Consumption of legumes like soybean, chickpea, and lentil rich in isoflavonoids daidzein, genistein and glycitein have been suggested to have multiple beneficial effects in a number of diseases, including certain types of cancer [160, 161]. Ziegler et al. [162] observed that Asian-American women who consumed a diet rich in soy had low risk of breast cancer incidence. Later studies of soy-rich diets confirmed that the main anti-breast cancer ingredient is genistein [163–165]. Dong et al. [166] in a meta-analysis of prospective studies pointed out that soybean isoflavonoid intake is associated with a significantly reduced risk of breast cancer incidence in Asian populations, but not in Western populations. Epidemiological indications jointly with clinical data from animal and in vitro studies highly supported a positive correlation between soybean isoflavonoid consumption and protection toward prostate cancers [164, 167]. Besides breast and prostate cancer, soy isoflavonoids also exhibit inhibitory effects on ovarian cancer, leukemia, and lung cancer [168].

Anticarcinogenic effect of carrot juice extracts on myeloid and lymphoid leukemia cell lines was investigated by Zaini et al. [169]. Carrot juice extracts owned the ability to "kill" leukemia cells and inhibit their progression. Those researchers believed that β-carotene and falcarinol present in the carrot juice extract may have been responsible for this positive effect. As a complement of this study, Larsen et al. [170] examined the impact of carrot and falcarinol feeding toward the development of azoxymethane-induced colon preneoplastic lesions in the rat colon. The results of this study demonstrated that diets with carrot and falcarinol have the potential to delay the development of large aberrant crypt foci and colon tumors on rats. Purup et al. [171] observed also that carrot extracts which contain falcarinol and related aliphatic C17-polyacetylenes (falcarindiol and falcarindiol 3-acetate) had significant inhibitory effect on intestinal cancer cell proliferation. Pisani et al. [172] in a case–control study show that smokers who eat carrots more than once a week have a smaller risk of lung cancer.

3.2 Effect on cardiovascular diseases

Vegetables offer protection against cardiovascular diseases since they are free of saturated fat, trans fat, and cholesterol and rich in bioactive compounds such as dietary fibers, OSCs, flavonoids, carotenoids, phytoestrogens, monoterpenes, and sterols. Unbalanced diets with low vegetable intake have been estimated to cause about 31% of ischemic heart disease and 11% of stroke worldwide [3]. A healthy diet with high vegetable consumption has been associated with lower risk of cardiovascular disease in humans [173, 174]. Liu et al. [175] test the influence of vegetable intake on the incidence of cardiovascular disease among 15,220 male physicians without a history of heart disease or stroke. The results of this investigation show that the participators who consumed more than two servings of vegetables per day had 25% less cardiovascular disease than those who consumed less than one serving. Based on this and other researches, the American Heart Association (AHA) has concluded that a diet high in vegetables and fruits may reduce the risk of cardiovascular disease in humans [176].

Prevention of cardiovascular diseases has been attributed to regular garlic consumption. Epidemiological studies demonstrate that there is an inverse correlation between garlic consumption and incidence of cardiovascular diseases [3, 74]. Yeh and Liu [177] show that garlic extracts and their OSCs have cholesterol and lipid-lowering effects by inhibiting monooxygenase and HMG-CoA reductase, two key enzymes involved in cholesterol and fatty acid synthesis. Moriguchi et al. [178] reported that garlic extracts have fibrinolytic effect by inhibiting lipid peroxidation and hemolysis of erythrocytes. Chang et al. [179] in their studies reported also the antiplatelet effect of sodium 2-propenyl thiosulfate from garlic, by inhibiting cyclooxygenase enzyme activity.

Similar to garlic, onions also contain a number of OSCs and flavonoids, such as quercetin, that can reduce the risks for cardiovascular diseases by increasing antioxidant capacity [3, 74, 180]. Hubbard et al. [181] in a pilot study in humans showed that the consumption of the equivalent of three onions in a soup was sufficient to significantly reduce the blood platelet aggregation. Platelet aggregation is an important risk for the development of coronary thrombosis and atherosclerosis. Briggs et al. [182] observed that by cutting raw onions S-alkenyl-L-cysteine sulfoxides are converted by enzyme alliinase into thiosulfinates and copaenes and these compounds inhibit platelet aggregation. Ried et al. [183] report also that onion and garlic had a blood pressure lowering effect by inhibiting angiotensin-converting enzyme activity and inducing intracellular nitric oxide and hydrogen sulfide production.

The consumption of leafy vegetables, due to bioactive compounds, increases antioxidant capacity and protects against oxidative stress which play an important role in the pathogenesis of cardiovascular diseases. Another reason is their low sodium and high calcium and magnesium content [3, 74]. Furthermore, that consumption also reduces blood pressure, inhibits platelet aggregation, and improves endothelial dysfunction due to their rich inorganic nitrate content [184]. In diets where the consumption of leafy vegetables is high, the rate of cardiovascular diseases is lower compared with diets with less consumption [3, 74, 185]. Rastogi et al. [186] observed that individuals with consumption of more than three portions of leafy vegetables a day have an incidence of about 60% less of ischemic heart disease than those consuming less than one portion. Saluk et al. [187] report that anthocyanin extracted from red cabbage has a protective effect on blood platelets.

In broccoli, indole-3-carbinol and sulforaphane, which are hydrolysis breakdown products of glucosinolate glucoraphanin, are thought to be the major bioactive compounds protective against cardiovascular diseases [188, 189]. Jeffery and Araya [189] report that indole-3-carbinol and sulforaphane besides protecting against ischemic damage of the heart also protect against inflammation by inhibiting cytokine production [189]. Murashima et al. [190] reported in a study, with multiple biomarkers for metabolism and oxidative stress, that broccoli sprouts decrease levels of total cholesterol and low-density lipoprotein cholesterol and increase levels of high-density lipoprotein cholesterol.

Jorge et al. [191] show in their studies that eggplant is effective in the treatment of high blood cholesterol. Guimarães et al. [192] showed a significant decrease in blood levels of total cholesterol and low-density lipoprotein cholesterol in human volunteers who were fed with eggplant powder. Kwon et al. [193] presented eggplant phenolics as inhibitors of key enzymes relevant for type 2 diabetes and hypertension.

Legumes are also protective against cardiovascular diseases due to their high saponin and soluble fiber content [2, 3, 74]. Soluble fiber delays gastric emptying, slows glucose absorption, and lowers serum cholesterol levels [194]. In several epidemiologic studies, a positive correlation between increased legume consumption and reduced mortality due to cardiovascular disease was observed [195, 196]. Consumption of legumes reduces the levels of total cholesterol and low-density lipoprotein cholesterol by inhibiting the absorption of bile acid from intestines and by promoting the formation of propionic acid and other short-chain fatty acids that inhibit the synthesis of cholesterol [197].

Nicolle et al. [198] suggest that carrot intake may exert a protective effect against cardiovascular disease and that this protective effect may be due to the synergistic action of dietary fiber and antioxidant polyphenols in carrot. Gramenzi et al. [199] state that the consumption of carrots is associated with smaller risk of acute myocardial infarction in women. Gilani et al. [200] examined in rats the antihypertensive effect of DC-2 and DC-3, two coumarin glycosides from carrot. Their results showed that these glycoside compounds caused a decrease in arterial blood pressure in the rats. Further in vitro studies by the same researchers demonstrate that the decreased blood pressure observed may be due to the calcium channel blocking action of coumarin glycosides DC-2 and DC-3 from carrots.

3.3 Effect on diabetes

Dias and Imai [95] highlight the nutritional and health benefits of different vegetables and their dietary fiber, vitamin C, vitamin E, carotenoids, flavonoids, thiosulfates, magnesium, selenium, zinc, and chromium contents, to prevent and reverse diabetes. Besides they also analyzed when we should eat the vegetables, and mainly the effect of eating vegetables before carbohydrates on postprandial blood glucose levels, and glycemic control. Data of these authors shows that eating vegetables before carbohydrates is effective to reduce postprandial hyperglycemia in type 2 diabetes patients, as well as in healthy people. So, vegetables should be eaten before carbohydrates at every meal [95].

Carter et al. [201] in a systematic review and meta-analysis found that greater leafy vegetable consumption was colligated with 14% decrease in risk of type 2 diabetes. Another previous research reported that each daily serving of leafy green vegetables generates a 9% decrease in risk of type 2 diabetes [202]. Khan et al. [203] saw that oral feeding of regular rats for 60 days with a mustard (Brassica juncea) diet (10% w/w) led to significant hypoglycemic effect. This result was associated to the positive stimulation of glycogen synthetase and to the suppression of glycogen phosphorylase and some other gluconeogenic enzymes. As mentioned Swiss chard leaves contain syringic acid that have blood sugar-regulating properties [91–93]. Syringic acid was demonstrated to inhibit the activity of α-glucosidase enzyme. When α-glucosidase gets inhibited, fewer carbohydrates are converted to sugars, and blood sugar is able to remain more steady [204]. Garden beet leaves have the same properties, since beet and Swiss chard are both from the Chenopodiaceae family [3, 74]. Yoshikawa et al. [205] in an oral glucose tolerance test (OGTT) conducted in rats, that measures the body's ability to metabolize glucose [206], observed that several glycosides isolated from the root extract of beet increase glucose tolerance. Gu et al. [207] report that purslane had hypoglycemic effects in a study comparing the hypoglycemic and antioxidant activities of the fresh and dried purslane in insulin-resistant HepG2 cells and streptozotocin-induced diabetic mice. In another study in adult patients with type 2 diabetes, it was found that consumption of purslane extract significantly reduced HbA1c levels and postprandial blood glucose [208].

Alliaceae vegetables are necessary ingredients of a diabetes prevention diet. Garlic lowers blood sugar levels in diabetic patients [209], and administration of S-methyl cysteine sulfoxide isolated from onion restrained blood glucose and showed significant hypoglycemic effect in rats [2, 74]. El-Demerdash et al. [210] in a biochemical study on the hypoglycemic effects of onion and garlic in alloxan-induced diabetic rats report that these vegetables had a hypoglycemic effect. Other investigations evaluating the hypoglycemic, antioxidant, and hepatoprotective potentials of onion show that onion consumption increased the levels of enzymes superoxide dismutase, catalase, and glutathione peroxidase [211] and reduce insulin resistance [212]. Onions and other Alliaceae also contain chromium that is linked to diabetes prevention by enhancing insulin receptor kinases [213]. Clinical surveys on diabetic patients showed that chromium can decrease fasting glucose, ameliorate glucose tolerance, and bring down insulin levels. Swamy et al. [209] observed that 200 g of some cultivars of onions contain chromium up to 20% of the daily requirements.

Nutritionists and dieticians commonly recommend diabetic eating carrots in moderation because they say that carrots contain more sugar than other vegetables. Although carrots are not a negative vegetable for the diabetic since they have fiber-rich fractions that transports a significant amount of polyphenols and carotenoids linked to the fiber matrix, they are relatively low in calories and the glycemic load is only 3 [97]. Glycemic effect of carrots when eaten raw is lessened further as the body does not absorb all of the calories in raw aliments [3, 74]. Chau et al. [214] comparing the characteristics, functional properties, and in vitro hypoglycemic effects of various carrot-insoluble fiber-rich fractions confirmed the great relationship between dietary fiber intake and lower risk of type 2 diabetes since those authors concluded, from their study, that the enhanced glucose absorbance capacity and reduction of amylase activity of dietary fiber of carrot help control postprandial serum glucose level. The recent research advocates that orange carrot with α- and β-carotene might help diabetics to succeed in their illness [97, 215]. Purple carrots, rich in anthocyanins and low in carotenoids, were also recently associated with reduction in impaired glucose tolerance [96].

Cucurbitaceae is a very important family for diabetics since it includes several vegetables with antidiabetic properties. Bitter gourd (Momordica charantia) has been intensively studied for its antidiabetic attributes. Different studies reported hypoglycemic and antihyperglycemic properties of bitter gourd [209, 216–218]. Clinical surveys on diabetic patients using pulp and juice extracts of bitter gourd were reported to bring down serum insulin levels, to lower fasting blood glucose levels, and to ameliorate glucose tolerance [219]. Vicine, charantin, and polypeptide-p are the principal hypoglycemic bioactive compounds from bitter gourd [220]. But there are also carotenoids (β-carotene, lutein, and zeaxanthin), triterpenoids (momordicin), alkaloids, and saponins, responsible for their side effect on glycemic control [221]. Momordicin possess insulin-like activity [222].

Besides bitter gourd other non-sweet Cucurbitaceae that have antidiabetic properties are ivy gourd (Coccinia grandis), snake gourd (Trichosanthes cucumerina), and ridge gourd (Luffa acutangula). In ivy gourd, immature fruits have antihyperglycemic properties since they help regulate blood sugar levels [223]. In India, they are used to prevent or treat diabetes [223]. Bioactive compounds in the ivy gourd inhibit glucose-6-phosphatase [209], a liver enzyme involved in the regulation of sugar metabolism. Snake gourd is also considered to be useful in treating type 2 diabetes [209]. Ridge gourd contains insulin like peptides and alkaloids that help to lower fasting blood glucose levels [209, 217].

Legume consumption is also colligated with reduced risk of type 2 diabetes since they are the ideal carbohydrate source [3, 90, 224]. They are low in glycemic load due to their moderate protein and abundant dietary fiber and resistant starch (that is fermented by bacteria in the colon). This chemical composition of legumes decreases the number of calories that can be absorbed which contribute to the control of blood sugar levels.

Kwon et al. [193] presented eggplant phenolics as inhibitors of key enzymes relevant for type 2 diabetes and hypertension.

4. Conclusions

Consumption of a vegetable-rich diet has unquestionable positive effects on nutrition and health since vegetables are rich in bioactive compounds such as dietary fiber, vitamins, minerals, and phytochemicals that can protect the human body from several types of chronic and degenerative diseases. The mechanism by which vegetable bioactive compounds decrease the risk of some of these diseases is complex and sometimes unknown. In this chapter, some experimental research evidences that the bioactive compounds are responsible for mitigating some human diseases were presented. All the different bioactive compounds may contribute to the overall health benefit. Each vegetable family and each vegetable contain a unique combination of bioactive compounds. So, the health benefit of vegetables should not be linked to only one bioactive compound or one type of vegetable but rather with a balanced diet that includes more than one type of vegetable. Antioxidative, anticarcinogenic, antidiabetic, and cardiovascular disease-lowering effects of vegetables have been reported. Nutrition is both a quantity and quality issue. The availability of a large diversity of vegetables all year-round allied to increase in mean per capita incomes in recent years, and knowledge of vegetable nutritional quality and health benefits should enable consumers to include more and more a great variety of health-promoting vegetables in their diet.

Conflict of interest

There is no "conflict of interest."

Author details

João Silva Dias
Instituto Superior de Agronomia, University of Lisbon, Lisbon, Portugal

*Address all correspondence to: mirjsd@gmail.com

References

[1] Dias JS, Ryder E. World vegetable industry: Production, breeding, trends. Horticultural Reviews. 2011;**38**:299-356

[2] Dias JS. Major classes of phytonutriceuticals in vegetables and health benefits: A Review. Journal of Nutritional Therapeutics. 2012;**1**:31-62

[3] Dias JS. Vegetable breeding for nutritional quality and health benefits. In: Carbone K, editor. Cultivar: Chemical Properties, Antioxidant Activities and Health Benefits. Hauppauge, New York: Nova Science Publishers Inc.; 2012. pp. 1-81

[4] Prior RL, Cao G. Antioxidant phytochemicals in fruit and vegetables, diet and health implications. Hortscience. 2000;**35**:588-592

[5] Hyson D. The Health Benefits of Fruit and Vegetables. A Scientific Overview for Health Professionals. Wilmington, DE: Produce for Better Health Foundation; 2002

[6] Golberg G, editor. Plants: Diet and Health. The Report of a British Nutrition Foundation Task Force. Oxford: Blackwell Science; 2003

[7] IFAVA. Fruit, vegetables and health: A scientific overview. International Fruit and Vegetable Alliance (IFAVA). Fruit, vegetables and health: a scientific overview. International Fruit and Vegetable Alliance. Ottawa, Canada; 2006

[8] Malaterreb AS, Remizeb F, Pouchereta P. Fruits and vegetables, as a source of nutritional compounds and phytochemicals. Changes in bioactive compounds during lactic fermentation. Food Research International. 2018;**104**:86-99

[9] Saura-Calixto F, Goñi I. Antioxidant capacity of the Spanish Mediterranean diet. Food Chemistry. 2006;**94**(3):442-447

[10] Saura-Calixto F, Serrano J, Goñi I. Intake and bioaccessibility of total polyphenols in a whole diet. Food Chemistry. 2007;**101**:492-501

[11] Kays SJ, Dias JS. Common names of commercially cultivated vegetables of the world in 15 languages. Economic Botany. 1995;**49**:115-152. DOI: 10.1007/BF02862917

[12] Kays SJ. Cultivated Vegetables of the World: A Multi-lingual Onomasticon. The Netherlands: Wageningen Academic Publishers; 2011. DOI: 10.3920/978-90-8686-720-2

[13] Dias JS. Major classes of phytonutriceuticals in vegetables and health benefits: A review. In: Nath P, editor. The Basics of Human Civilization-Food, Agriculture and Humanity, Volume-II-Food. New Delhi, India: Prem Nath Agricultural Science Foundation (PNASF), Bangalore & New India Publishing Agency (NIPA); 2014. pp. 305-370

[14] Nielsen SE, Young JF, Daneshvar B, Lauriden ST, Knuthsen P, Sandrstromand B, et al. Effect of parsley (*Petroselinum crispum*) intake on urinary apigenin excretion, blood antioxidant enzymes and biomarkers for oxidative stress in human subjects. The British Journal of Nutrition. 1999;**81**:447-455

[15] Horbowicz M, Kosson R, Grzesiuk A, Bski HD. Anthocyanins of fruits and vegetables—Their occurrence analysis and role in human nutrition. Vegetable Crops Research Bulletin. 2008;**68**:5-22

[16] Lila MA. Anthocyanins and human health: An in vitro investigative approach. Journal of Biomedicine and Biotechnology. 2004;**5**:306-313

[17] Ching LS, Mohamed S. Alpha-tocopherol content of 62 edible tropical plants. Journal of Agricultural and Food Chemistry. 2001;**49**:3101-3105

[18] Crozier A, Burns J, Aziz AA, Stewart AJ, Rabiasz HS, Jenkins GI, et al. Antioxidant flavonols from fruits, vegetables and beverages: Measurements and bioavailability. Biological Research. 2000;**33**:79-88

[19] Prakash D, Nath P, Pal M. Composition, variation of nutritional contents in leaves, seed protein, fat and fatty acid profile of *Chenopodium* species. Journal of the Science of Food and Agriculture. 1993;**62**:203-205

[20] Sienera R. Oxalate contents of species of the *Polygonaceae*, *Amaranthaceae* and *Chenopodiaceae* families. Food Chemistry. 2006;**98**:220-224

[21] Dhillon NPS, Monforte AJ, Pitrat M. Melon landraces of India: Contributions and importance. Plant Breeding Reviews. 2012;**35**:85-150

[22] Burger Y, Yeselson Y, Saar U, Paris HS, Katzir N, Tadmor Y, et al. Screening of melon (*Cucumis melo*) germplasm for consistently high sucrose content and for high ascorbic acid content. In: Lebeda A, Paris HS, editors. Progress in Cucurbit Genetics and Breeding Research. Proc Cucurbitaceae 2004. Olomouc, Czech Republic: Palacky University; 2004. pp. 151-155

[23] Crosby KM, Lester GE, Leskovar DI. Genetic variation for beneficial phytochemical levels in melons (*Cucumis melo*). In: Holmes GJ, editor. Cucurbitaceae 2006. Raleigh, NC: Universal Press; 2006. pp. 70-76

[24] Misra SK. Anti-nutritive bioactive compounds present in unconventional pulses and legumes. Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2012;**3**:586-597

[25] Mallillin AC, Trinidad TP, Raterta R, Dagbay K, Loyola AS. Dietary fiber and fermentability characteristics of root crops and legumes. The British Journal of Nutrition. 2008;**100**:485-488

[26] Trinidad TP, Mallillin AC, Loyola AS, Sagum RS, Encabo RR. The potential health benefits of legumes as a good source of dietary fiber. The British Journal of Nutrition. 2010;**103**:569-574

[27] Dias JS. World importance, marketing and trading of vegetables. Acta Horticulturae. 2011;(921):153-169

[28] Fahey JW, Zalcmann AT, Talalay P. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. Phytochemistry. 2001;**56**:5-51

[29] VanEtten CH, Dzenbichler ME, Williams P, Kwolek WF. Glucosinolates and derived products in cruciferous vegetables. Analysis in the edible part from twenty-two varieties of cabbage. Journal of Agricultural and Food Chemistry. 1976;**24**:452-455

[30] Carlson DG, Daxenbichler ME, Van Etten CH, Tookey HL, Williams PH. Glucosinolates in crucifer vegetables: Turnip and rutabagas. Journal of Agricultural and Food Chemistry. 1981;**29**:1235-1239

[31] Carlson DG, Daxenbichler ME, VanEtten CH, Hill CB, Williams PH. Glucosinolates in radish cultivars. Journal of the American Society for Horticultural Science. 1985;**110**:634-638

[32] Carlson DG, Daxenbichler ME, VanEtten CH, Kwolek WF, Williams PH. Glucosinolates in crucifer vegetables: Broccoli, Brussels sprouts, cauliflower, collards, kale, mustard green, and kohlrabi. Journal of the American Society for Horticultural Science. 1987a;**112**:173-178

[33] Carlson DG, Daxenbichler ME, VanEtten CH, Kwolek WF, Hill CB, Williams PH. Glucosinolates in turnip tops and roots: Cultivars grown for

greens and/or roots. Journal of the American Society for Horticultural Science. 1987b;**112**:179-183

[34] Kushad MK, Brown AF, Kurillicn AC, Juvik JA, Klein BP, Wallig MA, et al. Variation in glucosinolates in vegetable crops of *Brassica oleracea*. Journal of Agricultural and Food Chemistry. 1999;**47**:1541-1548

[35] Ciska E, Martyniak-Przybyszewska B, Kozlowska H. Content of glucosinolates in cruciferous vegetables grown at the same site for two years under different climatic condition. Journal of Agricultural and Food Chemistry. 2000;**48**:2862-2867

[36] Vallejo F, Tomas-Barberan FA, Banavent-Garcia AG, Garcia-Viguera C. Total and individual glucosinolate contents in inflorescences of eight broccoli cultivars grown under various climatic and fertilization conditions. Journal of the Science of Food and Agriculture. 2003;**83**:307-313

[37] Nilsson J, Olsson K, Engqvist G, Ekvall J, Olsson M, Nyman M, et al. Variation in the content of glucosinolates, hydroxycinnamic acids, carotenoids, total antioxidant capacity and low-molecular-weight carbohydrates in *Brassica* vegetables. Journal of the Science of Food and Agriculture. 2006;**86**:528-538

[38] Borkowski J, Szajdek A, Borkowska EJ, Ciska E, Zielinski H. Content of selected bioactive components and anti oxidant properties of broccoli (*Brassica oleracea* L.). European Food Research and Technology. 2008;**226**:459-465

[39] Cartea ME, Velasco P, Obregón S, Padilla G, de Haro A. Seasonal variation in glucosinolate content in *Brassica oleracea* crops grown in northwestern Spain. Phytochemistry. 2008;**69**:403-410

[40] Hansen M, Bengtsson GB, Borge GI, Berge L, Wold AB. Red cabbage, a vegetable rich in health-related glucosinolates. Acta Horticulturae. 2010;**867**:61-65

[41] Fahey JW, Zhang YS, Talalay P. Broccoli sprouts: An exceptionally rich source of inducers of enzymes that protects against chemical carcinogens. Proceedings of the National Academy of Sciences of the United States of America. 1997;**94**:10367-10372

[42] Goodrich RM, Anderson JL, Stoewsand G. Glucosinolate changes in blanched broccoli and brussels sprouts. Journal of Food Processing and Preservation. 1989;**13**:275-280

[43] Vallejo F, Tomas-Barberan FA, Garcia-Viguera C. Potential bioactive compounds in health promotion from broccoli cultivars grown in Spain. Journal of the Science of Food and Agriculture. 2002;**82**:1293-1297

[44] Kusznierewics B, Bartoszek A, Wolska L, Drzewiwcki J, Gorinstein S, Namiesnik J. Partial characterization of white cabbages (*Brassica oleracea* var. *capitata* f. *alba*) from different regions by glucosinolates, bioactive compounds, total antioxidant activities and proteins. LWT-Food Science and Technology. 2008;**41**:1-9

[45] Cao G, Sofic E, Prior RL. Antioxidant capacity of tea and common vegetables. Journal of Agricultural and Food Chemistry. 1996;**44**:3426-3431

[46] Scott J, Releille F, Fletcher J. Folic acid and folates: The feasibility for nutritional enhancement in plant foods. Journal of Science and Food Agriculture. 2000;**80**:795-824

[47] Konings EJM, Roomans HH, Dorant E, Goldbohm RA, Saris WH, van den Brandt PA. Folate intake of the Dutch population according to newly established liquid chromatography data for foods. The American Journal of Clinical Nutrition. 2001;**73**:765-776

[48] Banuelos G, Meek D. Selenium accumulation in selected vegetables. Journal of Plant Nutrition. 1989;**12**:1255-1272

[49] Nencini C, Cavallo F, Capasso A, Franchi GG, Giorgio G, Micheli L. Evaluation of antioxidative properties of *Allium* species growing wild in Italy. Phytotherapy Research. 2007;**21**:874-878

[50] Kalra N, Arora A, Shukla Y. Involvement of multiple signaling pathways in diallyl sulfide mediated apoptosis in mouse skin tumors. Asian Pacific Journal of Cancer Prevention. 2006;**7**:556-562

[51] Rose P, Whiterman M, Moore PK, Zhu YZ. Bioactive S-alk(en)yl cysteine sulfoxide metabolites in the genus *Allium*: The chemistry of potential therapeutic agents. Natural Product Reports. 2005;**22**:351-368

[52] Rubec R, Svobodovaand M, Velisek J. Gas chromatographic determination of S-alk(en)yl-L-cysteine sulfoxides. Journal of Chromatography. 1999;**862**:85-94

[53] Thomas DJ, Parkin KL. Quantification of alk(en)yl-L-cysteine sulfoxide and related amino acids in alliums by high-performance liquid chromatography. Journal of Agricultural and Food Chemistry. 1994;**42**:1632-1638

[54] Yoo KS, Pike LM. Determination of flavor precursor compound S-alk(en)yl-L-cysteine sulfoxides by HPLC method and their distribution in *Allium* species. Scientia Horticulturae. 1998;**75**:1-10

[55] Kubec R, Svobodova M, Velisek J. Gas-chromatographic determination of S-alk(eny)lylcysteine sulfoxide. Journal of Chromatography. 1999;**862**:85-94

[56] Miean KH, Mohamed S. Flavonoid (myricetin, quercetin, kaempferol, luteolinand apigenin) content of edible tropical plants. Journal of Agricultural and Food Chemistry. 2001;**49**:106-112

[57] Hertog MG, Hollman PC, Katan MB. Content of potentially anticarcinogenic flavonoids of 28 vegetables and fruits commonly consumed in The Netherlands. Journal of Agricultural and Food Chemistry. 1992;**40**:2379-2383

[58] Bilyk A, Sapers GM. Distribution of quercetin and kaemperol in lettuce, kale, chive, garlic chive leek, horseradish, red radish and red cabbage tissue. Journal of Agricultural and Food Chemistry. 1985;**33**:226-228

[59] Ip C, Lisk DJ. Enrichment of selenium in allium vegetables for cancer prevention. Carcinogenesis. 1994;**15**:1881-1885

[60] Clinton S. Lycopene: Chemistry, biology and implication for human health and disease. Nutrition Reviews. 1998;**56**:35-51

[61] Scott KJ, Hart DJ. Development and evolution of an HPLC method for the analysis of carotenoids food and the measurement of the carotenoid content vegetables and fruits commonly consumed in the UK. Food Chemistry. 1995;**54**:101-111

[62] Tonucci LH, Holden JM, Beecher GR, Khachik F, Davis CS, Mulokozi G. Carotenoid content of thermally processed tomato-based food products. Journal of Agricultural and Food Chemistry. 1995;**43**:579-586

[63] Gerster H. The potential role of lycopene for human health. Journal of the American College of Nutrition. 1997;**16**:109-126

[64] Agarwal S, Rao AK. Tomato lycopene and its role in human health and chronic diseases. Canadian Medical Association Journal. 2000;**163**:739-744

[65] Rao AV, editor. Tomatoes, Lycopene and Human Health Preventing Chronic Diseases. Stranraer, Scotland: Caledonian Science Press; 2006

[66] Leonardi C, Ambrosino P, Esposito F, Fogliano V. Antioxidant activity and carotenoid and tomatine contents in different typologies of fresh consumption tomatoes. Journal of Agricultural and Food Chemistry. 2000;**48**:4723-4727

[67] Arab L, Steck S. Lycopene and cardiovascular disease. The American Journal of Clinical Nutrition. 2000;**71**:1691S-1695S

[68] Rao AV, Rao LG. Carotenoids and human health. Pharmacological Research. 2007;**55**:207-216

[69] Albushita AA, Daood HG, Biacs PA. Change in carotenoids and antioxidant vitamins in tomato as a function of varietal and technological factors. Journal of Agricultural and Food Chemistry. 2000;**48**:2075-2081

[70] Albushita AA, Hebshi EA, Daood HG, Biacs PA. Determination of antioxidant vitamins in tomato. Food Chemistry. 1997;**60**:207-212

[71] Crozier A, Lean ME, McDonaldand MS, Black C. Quantitative analysis of the flavonoid content of commercial tomatoes, onions, lettuce and celery. Journal of Agricultural and Food Chemistry. 1997;**45**:590-595

[72] Stewart AJ, Bozonnet S, Mullen W, Jenkins GI, Lean ME, Crozier A. Occurrence of flavonols in tomatoes and tomato-based products. Journal of Agricultural and Food Chemistry. 2000;**48**:2663-2669

[73] Craig W, Beck L. Phytochemicals: Health protective effects. Canadian Journal of Dietetic Practice and Research. 1999;**60**:78-84

[74] Dias JS. Nutritional quality and health benefits of vegetables: A review. Food and Nutrition Sciences. 2012;**3**:1354-1374. DOI: 10.4263/fns.2012.310179

[75] Bosland PW. Capsicums: Innovative uses of an ancient crop. In: Janick J, editor. Progress in New Crops. Arlington, VA: ASHS Press; 1996. pp. 479-487

[76] Howard LR, Talcott ST, Brenes CH, Villalon B. Changes in phytochemical and antioxidant activity of selected pepper cultivars (*Capsicum* species) as influenced by maturity. Journal of Agricultural and Food Chemistry. 2000;**48**:1713-1720

[77] Howard LR, Smith RT, Wagner AB, Villalon B, Burns EE. Provitamin A and ascorbic acid content of fresh pepper cultivars (*Capsicum annum*) and processed jalapenos. Journal of Food Science. 1994;**59**:362-365

[78] Lee Y, Howard R, Villalon B. Flavonoids and antioxidant activity of fresh pepper (*Capsicum annum*) cultivars. Journal of Food Science. 1995;**60**:473-476

[79] Suzuki T, Iwai K. The alkaloids. In: Brossi A, editor. The Alkaloids Chemistry and Pharmacology. Vol. XXIII. San Diego, CA: Academic Press; 1984. pp. 227-229

[80] Thomas BV, Schreilber AA, Weisskopf CP. Simple method for quantitation of capsaicinoids in pepper using capillary gas chromatography. Journal of Agricultural and Food Chemistry. 1998;**46**:2655-2663

[81] Frei B, Lawson S. Vitamin C and cancer revisited. Proceedings of the National Academy of Sciences of the United States of America. 2008;**105**:11037-11038

[82] Noda Y, Kaneyuki T, Igarashi K, Moriand A, Pacer L. Antioxidant

activity of nasunin, an anthocyanin in eggplant. Research Communications in Molecular Pathology and Pharmacology. 1998;**102**:175-187

[83] Kayamori F, Igarashi K. Effect of dietary nasunin on the serum cholesterol level in rats. Bioscience, Biotechnology, and Biochemistry. 1994;**58**:570-571

[84] Noda Y, Kneyuki T, Igarashi K. Antioxidant activity of nasunin, an anthocyanin in eggplant peels. Toxicology. 2000;**148**:119-123

[85] Matsuzoe N, Yamaguchi M, Kawanobu S, Watanabe Y, Higashi H, Sakata Y. Effect of dark treatment of the eggplant on fruit skin color and its anthocyanin components. The Japanese Society for Horticultural Science. 1999;**68**:138-145

[86] Whitaker BD, Stommel JR. Distribution of hydroxycinnamic acid conjugates in fruit of commercial eggplant (*Solanum melongena* L.) cultivars. Journal of Agricultural and Food Chemistry. 2003;**51**:3448-3454

[87] Ben-Amos A, Fishler R. Analysis of carotenoids with emphasis on 9-cis β-carotene in vegetables and fruits commonly consumed in Israel. Food Chemistry. 1998;**62**:515-520

[88] Assimos DG, Holmes RP. Role of diet in the therapy of urolithiasis. The Urologic Clinics of North America. 2000;**27**:255-268

[89] Britton G, Khachik F. Carotenoids in food. In: Britton G, Pfander H, Liaaen-Jensens S, editors. Carotenoids. Baseline: Birkhäuser; 2009. pp. 45-66

[90] Fuhrman J. The End of Diabetes: The Eat to Live Plan to Prevent and Reverse Diabetes. New York: Harper Collins Publishers; 2013

[91] Pyo YH, Lee TC, Logendrac L, Rosen RT. Antioxidant activity and phenolic compounds of Swiss chard (*Beta vulgaris* subspecies *cycla*) extracts. Food Chemistry. 2004;**85**:19-26. DOI: 10.1016/S0308-8146(03)00294 -2

[92] Bolkent S, Yanarda R, Tabakolu-Oguz A, Ozsoy-Sacan O. Effects of chard (*Beta vulgaris* L. var. *cicla*) extract on pancreatic β cells in streptozotocin-diabetic rats: A morphological and biochemical study. Journal of Ethnopharmacology. 2000;**73**:251-259. DOI: 10.1016/S0378-8741(00)00328 -7

[93] Mateljan G. The World's Healthiest Foods. Glendale, California: George Mateljan Foundation; 2016

[94] Kugler F, Stintzing FC, Carle R. Identification of betalains from petioles of differently colored Swiss chard (*Beta vulgaris* L. ssp. *cicla* [L.] Alef. cv. Bright Lights) by high-performance liquid chromatography-electrospray ion. Journal of Agricultural and Food Chemistry. 2004;**52**: 2975-2981. DOI: 10.1021/jf035491w

[95] Dias JS, Imai S. Vegetables consumption and its benefits on diabetes. Journal of Nutritional Therapeutics. 2017;**6**:1-10

[96] Poudyal H, Panchal S, Brown L. Comparison of purple carrot juice and β-carotene in a high-carbohydrate, high-fat diet-fed rat model of the metabolic syndrome. The British Journal of Nutrition. 2010;**104**:1322-1332. DOI: 10.1017/S0007114510002308

[97] Dias JS. Nutritional and health benefits of carrots and their seed extracts. Food and Nutrition Sciences. 2014;**5**:2147-2156. DOI: 10.4236/fns.2014.522227

[98] Ferracane R, Pellegrini N, Visconti A, Graziani G, Chıavaro E, Miglio C, et al. Effects of different cooking methods on antioxidant profile, antioxidant capacity, and physical characteristics of artichoke. Journal

of Agricultural and Food Chemistry. 2008;**56**:8601-8608

[99] World Health Organization (WHO). Increasing Fruit and Vegetable Consumption to Reduce the Risk of Non-Communicable Diseases. World Health Organization. e-Library of Evidence for Nutrition Actions (eLENA). World Health Organization. Geneva, Switzerland; 2018

[100] Fergunson LR. Prospect of cancer prevention. Mutation Research. 1999;**428**:329-338

[101] American Institute of Cancer Research (AICR). Food, Nutrition, Physical Activity, and the Prevention of Cancer: A Global Perspective. Washington, DC: AIRC/World Cancer Research Fund; 2007

[102] Potter JD, Slattery ML, Bostick RM. Colon cancer: A review of the epidemiology. Epidemiologic Reviews. 1993;**15**:499-545

[103] van Duijnhoven FJ, Bueno-de-Mesquita HB, Ferrari P, Jenab M, Boshuizen HC, Ros MM, et al. Fruit, vegetables and colorectal cancer risk: The European prospective investigation into cancer and nutrition. The American Journal of Clinical Nutrition. 2009;**89**:1441-1452

[104] Trock B, Lanza E, Greenwald P. Dietary fiber, vegetables, and colon cancer: Critical review and meta-analysis of the epidemiologic evidence. Journal of the National Cancer Institute. 1990;**82**:650-661

[105] Neugut AI, Jacobson JS, DeVivo L. Epidemiology of colorectal adenomas: Macronutrients, cholesterol and fiber. Journal of the National Cancer Institute. 1993;**85**:884-891

[106] Steinmetz KA, Kushi LH, Bostick R, Folisom AR, Potter JD. Vegetable, fruit and colon cancer in the Iowa women's health study. American Journal of Epidemiology. 1994;**139**:1-15

[107] Witte JS, Longnecker MP, Bird SL, Lee ER, Frakl HD, Haile RW. Relation of vegetable, fruit and grain consumption to colorectal adenomatous polyps. American Journal of Epidemiology. 1996;**144**:1015-1025

[108] Iscovich JM, L'Abbe KA, Castelleto R, Calzona A, Bernaedo A, Chopita NA, et al. Colon cancer in Argentina. Risk from intake of dietary items. International Journal of Cancer. 1992;**51**:851-857

[109] Zaridize D, Filipchenco V, Kustov V. Diet and colorectal cancer: Results of two case-control studies in Russia. European Journal of Cancer. 1993;**29A**:113-115

[110] Tanaka S, Haruma K, Yoshihara M, Kajiyama G, Kira K, Amagase H, et al. Aged garlic extract has potential suppressive effect on colorectal adenomas in humans. The Journal of Nutrition. 2006;**136**:821S-826S

[111] Radhika G, Sudha V, Sathya RM, Ganesan A, Mohan V. Association of fruit and vegetable intake with cardiovascular risk factors in urban south Indians. The British Journal of Nutrition. 2008;**99**:398-405. DOI: 10.1017/S0007114507803965

[112] Soh Y, Shin M, Lee J, Jang J, Kim OH, Kang H, et al. Oxidative DNA damage and glioma cell death induced by tetrahydropapaveroline. Mutation Research. 2003;**544**:129-142. DOI: 10.1016/j.mrrev.2003.06.023

[113] Tao J, Li Y, Li S, Li HB. Plant foods for the prevention and management of colon cancer. Journal of Functional Foods. 2018;**42**:95-110. DOI: 10.1016/j.jff.2017.12.064

[114] Tewani R, Sharma JK, Rao SV. Spinach (Palak) natural laxative. International Journal of Applied Research and Technology. 2016;**1**:140-148. DOI: 10.4172/2157-7471.1000110

[115] Verhoeven DTH, Goldbohm RA, van Poppel G, Verhagen H, van den Brandt PA. Epidemiological studies on *Brassica* vegetables and cancer risk. Cancer Epidemiology, Biomarkers and Prevention. 1996;**5**:733-751

[116] Ambrosone CB, McCann SE, Freudenheim JL, Marshall JR, Zhang Y, Shields PG. Breast cancer risk in premenopausal women is inversely associated with consumption of broccoli, a source of isothiocyanates, but is not modified by GST genotype. The Journal of Nutrition. 2004;**134**:1134-1138

[117] Brennan P, Hsu CC, Moullan N, Szeszenia-Dabrowska N, Lissowska J, Zaridze D, et al. Effect of cruciferous vegetables on lung cancer in patients stratified by genetic status: A mendelian randomisation approach. Lancet. 2005;**366**:1558-1560

[118] Kirsh VA, Peters U, Mayne ST, Subar AF, Chatterjee N, Johnson CC, et al. Prospective study of fruit and vegetable intake and risk of prostate cancer. Journal of the National Cancer Institute. 2007;**99**:1200-1209

[119] Traka M. Broccoli consumption interferes with prostate cancer progression: Mechanisms of action. Acta Horticulturae. 2010;**867**:19-25

[120] Seow A, Yuan JM, Sun CL, Van Den Berg D, Lee HP, Yu MC. Dietary isothiocyanates, glutathione S-transferase polymorphisms and colorectal cancer risk in the Singapore Chinese health study. Carcinogenesis. 2002;**23**:2055-2061

[121] London SJ, Yuan JM, Chung FL, Gao YT, Coetzee GA, Ross RK, et al. Isothiocyanates, glutathione S-transferase M1 and T1 polymorphisms, and lung-cancer risk: A propective study of men in Shanghai, China. Lancet. 2000;**356**:724-729

[122] Fowke JH, Chung FL, Jin F, Qi D, Cai Q, Conaway C, et al. Urinary isothiocyanate levels, brassica, and human breast cancer. Cancer Research. 2003;**63**:3980-3986

[123] Joseph MA, Moysich KB, Freudenheim JL, Shields PG, Bowman ED, Zhamg Y, et al. Cruciferous vegetables, generic polymorphism in glutathione S-transferases M1 and T1, and prostate cancer risk. Nutrition and Cancer. 2004;**50**:206-213

[124] Juge N, Mithen RF, Traka M. Molecular basis for chemoprevention by sulforaphane: A comprehensive review. Cellular and Molecular Life Sciences. 2007;**64**:1105-1127

[125] Zhang Y, Talalay P. Anticarcinogenic activities of organic isothiocyanate : Chemistry and mechanisms. Cancer Research. 1994;**54**:1976s-1981s

[126] Mithen R, Faulkner K, Magrath R, Rose P, Williamson G, Marquez J. Development of isothiocyanate enriched broccoli and its enhanced ability to induce phase 2 detoxification enzymes in mammalian cells. Theoretical and Applied Genetics. 2003;**106**:727-734

[127] Rosa EAS, Heaney RK, Fenewick GR, Portas CAM. Glucosinolates in crop plants. Horticultural Reviews. 1997;**19**:99-215

[128] Abbaoui B, Lucas CR, Riedl KM. Cruciferous vegetables, isothiocyanates, and bladder cancer prevention. Molecular Nutrition and Food Research. 2018;**62**:1-50

[129] Dorant E, van Den Brandt PA, Goldbohm RA, Sturnmans F. Consumption of onions and a reduced risk of stomach carcinoma. Gastroenterology. 1996;**110**:12-20

[130] You WC, Li JY, Zhang L, Jin ML, Chang YS, Ma JL, et al. Etiology and prevention of gastric cancer: A population study in high risk area of

China. Chinese Journal of Digestive Diseases. 2005;**6**:149-154

[131] Galeone C, Pelucchi C, Levi F, Negri E, Franceschi S, Talamini R, et al. Onion and garlic use and human cancer. The American Journal of Clinical Nutrition. 2006;**84**:1027-1032

[132] Grant WB. A multicountry ecologic study of risk and risk reduction factors for prostate cancer mortality. European Urology. 2004;**45**:271-279

[133] Shon MY, Choi SD, Kahng GG, Nam SH, Sung NJ. Antimutagenic, antioxidant and free radical scavenging activity of ethyl acetate extracts from white, yellow and red onions. Food and Chemical Toxicology. 2004;**42**:659-666

[134] Yang J, Meyers KJ, vander Heide J, Liu RH. Varietal differences in phenolic content and antioxidant and antiproliferative activities of onions. Journal of Agricultural and Food Chemistry. 2004;**52**:6787-6793

[135] Kim JY, Kwon O. Garlic intake and cancer risk: An analysis using the Food and Drug Administration's evidence-based review system for the scientific evaluation of health claims. The American Journal of Clinical Nutrition. 2009;**89**:257-264

[136] Salem S, Salahi M, Mohseni M, Ahmadi H, Mehrsai A, Jahani Y, et al. Major dietary factors and prostate cancer risk: A prospective multicenter case-control study. Nutrition and Cancer. 2011;**63**:21-27

[137] Iciek M, Kwiecien I, Wlodek L. Biological properties of garlic and garlic-derived organosulfur compounds. Environmental and Molecular Mutagenesis. 2009;**50**:247-265

[138] Melino S, Sabelli R, Paci M. Allyl sulfur compounds and cellular detoxification system: Effects and perspectives in cancer therapy. Amino Acids. 2011;**41**:103-112

[139] You WC, Zhang L, Gail MH, Ma JL, Chang YS, Blot WJ, et al. *Helicobacter pylori* infection, garlic intake and precancerous lesions in a Chinese population at low risk of gastric cancer. International Journal of Epidemiology. 1998;**27**:941-944

[140] Tanaka S, Haruma K, Kunihiro M, Nagata S, Kitadai Y, Manabe N, et al. Effects of aged garlic extract (AGE) on colorectal adenomas: A double-blinded study. Hiroshima Journal of Medical Sciences. 2004;**53**:39-45

[141] Fleischauer AT, Poole C, Arab L. Garlic consumption and cancer prevention: Meta-analyses of colorectal and stomach cancers. The American Journal of Clinical Nutrition. 2000;**72**:1047-1052

[142] Hsing AW, Chokkalingam AP, Gao YT, Madigan MP, Deng J, Gridley G, et al. Allium vegetables and risk of prostate cancer: A population-based study. The Journal of the National Cancer Institute. 2002;**94**:1648-1651

[143] Challier B, Perarnau JM, Viel JF. Garlic, onion and cereal fibre as protective factors for breast cancer: A French case-control study. European Journal of Epidemiology. 1998;**14**:737-747

[144] Galeone C, Pelucchi C, Dal Maso L, Negri E, Montella M, Zucchetto A, et al. Allium vegetables intake and endometrial cancer risk. Public Health Nutrition. 2009;**12**:1576-1579

[145] Satia JA, Littman A, Slatore CG, Galanko JA, White E. Associations of herbal and specialty supplements with lung and colorectal cancer risk in the vitamins and lifestyle study. Cancer Epidemiology, Biomarkers and Prevention. 2009;**18**:1419-1428

[146] Wang Y, Tian W, Ma X. Inhibitory effects of onion (*Allium cepa* L.) extract on proliferation of cancer cells

and adipocytes via inhibiting fatty acid synthase. Asian Pacific Journal of Cancer Prevention. 2012;**13**:5573-5579. DOI: 10.7314/APJCP.2012.13.11.5573

[147] Burney PG, Comstock GW, Morris JS. Serologic precursors of cancer: Serum micronutrients and the subsequent risk of pancreatic cancer. The American Journal of Clinical Nutrition. 1989;**49**:895-900

[148] Van Eenwyk J, Davis FG, Bowen PE. Dietary and serum carotenoids and cervical intraepithelial neoplasia. International Journal of Cancer. 1991;**48**:34-38

[149] Franceschi S, Bidoli E, La Vecchia C, Talamini R, D'Avanzo B, Negri E. Tomatoes and risk of digestive-tract cancers. International Journal of Cancer. 1994;**59**:181-184

[150] Helzlsouer KJ, Comstock GW, Morris JS. Selenium, lycopene, alpha-tocopherol, beta-carotene, retinol, and subsequent bladder cancer. Cancer Research. 1989;**49**:6144-6148

[151] Gann PH, Ma J, Giovannucci E. Lower prostate cancer risk in men with elevated plasma lycopene levels: Results of a prospective analysis. Cancer Research. 1999;**59**:1225-1230

[152] Yuan JM, Ross RK, Gao YT, Qu YH, Chu XD, Yu MC. Prediagnostic levels of serum micronutrients in relation to risk of gastric cancer in Shanghai, China. Cancer Epidemiology, Biomarkers and Prevention. 2004;**13**:1772-1780

[153] Wakai K, Ando M, Ozasa K. Updated information on risk factors for lung cancer: Findings from the JACC Study. Journal of Epidemiology. 2005;**15**:S134-S139

[154] Giovannucci E. Tomatoes, tomato based products, lycopene and cancer: Review of the epidemiological literature. The Journal of the National Cancer Institute. 1999;**91**:317-331

[155] Jang J, Surh Y. Potentiation of cellular antioxidant capacity by Bcl-2: Implications for its antiapoptotic function. Biochemical Pharmacology. 2003;**66**:1371-1379. DOI: 10.1016/S0006-2952(03)00487-8

[156] Hadley CW, Miller EC, Schwartz SJ, Clinton SK. Tomatoes, lycopene, and prostate cancer: Progress and promise. Experimental Biology and Medicine. 2002;**227**:869-880. DOI: 10.1177/153537020222701006

[157] Giovannucci E, Ashcerio A, Rimm EB. Intake of carotenoids and retinol in relation to risk of prostate cancer. Journal of the National Cancer Institute. 1995;**87**:1767-1776

[158] Clark R, Lee SH. Anticancer properties of capsaicin against human cancer. Anticancer Research. 2016;**36**:837-844

[159] Nagase H, Sasaki K, Kito H, Haga A, Sato T. Inhibitory effect of delphinidin from *Solanum melongena* on human fibrosarcoma HT-1080 invasiveness in vitro. Planta Medica. 1998;**64**:216-219

[160] Goldwyn S, Lazinskyand A, Wei H. Promotion of health by soy isoflavones: Efficacy, benefit and safety concerns. Drug Metabolism and Drug Interactions. 2000;**17**:261-289

[161] Sarkar FH, Li Y. Isoflavones, soybean phytoestrogens, and cancer. In: Awad AB, Bradford PG, editors. Nutrition and Cancer Prevention. Boca Raton, FL: CRC Press; 2006. pp. 295-312

[162] Ziegler RG, Hooverand RN, Hildeshein RN. Migration patterns and breast cancer risk in Asian-America women. The Journal of the National Cancer Institute. 1993;**85**:1819-1827

[163] Lamartiniere C. Protection against breast cancer with genistein: A component of soy. The American Journal of Clinical Nutrition. 2000;**71**:1705S-1707S

[164] Steiner C, Arnould S, Scalbert A, Manach C. Isoflavones and the prevention of breast and prostate cancer: New perspectives opened by nutrigenomics. The British Journal of Nutrition. 2008;**99**:78-108

[165] Messina MJ, Wood CE. Soy isoflavones, estrogen therapy, and breast cancer risk: Analysis and commentary. Nutrition Journal. 2008;**7**:17. DOI: 10.1186/1475-2891-7-17

[166] Dong JY, Qin LQ. Soy isoflavones consumption and risk of breast cancer incidence or recurrence: A meta-analysis of prospective studies. Breast Cancer Research and Treatment. 2011;**125**:315-323

[167] Jiang HY, Lv FJ, Tai JQ. Bioactive components of soybean and their function. Soybean Science. 2000;**19**:160-164

[168] Sarkar FH, Li Y. Soy isoflavones and cancer prevention. Cancer Investigation. 2003;**21**:744-757

[169] Zaini R, Clench MR, Maitre CL. Bioactive chemicals from carrot (*Daucus carota*) juice extracts for the treatment of leukemia. Journal of Medicinal Food. 2011;**14**:1303-1312. DOI: 10.1089/jmf.2010.0284

[170] Larsen MK, Christensen LP, Vach W, Hoitinga RJ, Brant K. Inhibitory effects of feeding with carrots or falcarinol on development of azoxymethane-induced preneoplastic lesions in the rat colon. Journal of Agricultural and Food Chemistry. 2005;**53**:1823-1827. DOI: 10.1021/jf048519s

[171] Purup S, Larsen E, Christesen LP. Differential effects of falcarinol and related aliphatic C17-polyacetylenes on intestinal cell proliferation. Journal of Agricultural and Food Chemistry. 2009;**57**:8290-8296. DOI: 10.1021/jf901503a

[172] Pisani P, Berrino F, Macaluso M, Pastorino U, Crosignani P, Baldasseroni A. Carrots, green vegetables and lung cancer: A case-control study. International Journal of Epidemiology. 1986;**15**:463-468. DOI: 10.1093/ije/15.4.463

[173] Mullie P, Clarys P. Association between cardiovascular disease risk factor knowledge and lifestyle. Food and Nutrition Sciences. 2011;**2**:1048-1053

[174] Roth GA, Forouzanfar MH, Moran AE, Barber R, Nguyen G, Feigin VL, et al. Demographic and epidemiologic drivers of global cardiovascular mortality. The New England Journal of Medicine. 2015;**372**:1333-1341. DOI: 10.1056/NEJMoa1406656

[175] Liu S, Lee IM, Ajani U, Cole SR, Buring JE, Manson JE. Intake of vegetables rich in carotenoids and risk of coronary heart disease in men: The physicians' health study. International Journal of Epidemiology. 2001;**30**:130-135

[176] American Heart Association (AHA). Heart and stroke statistical update. Dallas, Texas: American Heart Association; 2017

[177] Yeh YY, Liu L. Cholesterol-lowering effect of garlic extracts and organosulfur compounds: Human and animal studies. The Journal of Nutrition. 2001;**131**:989-993. DOI: 10.1093/jn/131.3.989S

[178] Moriguchi T, Takasugi N, Itakura Y. The effects of aged garlic extract on lipid peroxidation and the deformability of erythrocytes. The Journal of Nutrition. 2001;**131**:1016-1019. DOI: 10.1093/jn/131.3.1016S

[179] Chang HS, Yamato O, Yamasaki M, Maede Y. Modulatory influence of sodium 2-propenylthiosulfate from garlic on cyclooxygenase activity in canine platelets: Possible mechanism

for the anti-aggregatory effect. Prostaglandins, Leukotrienes, and Essential Fatty Acids. 2005;**72**:351-355. DOI: 10.1016/j.plefa.2005.01.003

[180] Osmont KS, Arnt CR, Goldman IL. Temporal aspects of onion-induced antiplatelet activity. Plant Food for Human Nutrition. 2003;**58**:27-40

[181] Hubbard GP, Wolffram S, Lovegrove JA, Gibbins JM. Ingestion of quercetin inhibits platelet aggregation and essential components of the collagen-stimulated platelet activation pathway in man: A pilot study. Journal of Thrombosis and Haemostasis. 2006;**2**:2138-2145

[182] Briggs WH, Folts JD, Osman HE, Goldman IL. Administration of raw onion inhibits platelet-mediated thrombosis in dogs. The Journal of Nutrition. 2001;**131**:2619-2622. DOI: 10.1093/jn/131.10.2619

[183] Ried K, Frank OR, Stocks NP. Aged garlic extract reduces blood pressure in hypertensives: A dose–response trial. European Journal of Clinical Nutrition. 2013;**67**:64-70. DOI: 10.1038/ejcn.2012.178

[184] Freudenheim JL, Graham S, Marshall JR, Haughey BP, Wilkinson G. A case-control study of diet and rectal cancer in western New York. American Journal of Epidemiology. 1990;**131**:612-624

[185] Knekt P, Jarvinen R, Reunanen A, Maatela J. Flavonoid intake and coronary mortality in Finland: A cohort study. British Medical Journal. 1996;**312**:478-481. DOI: 10.1136/bmj.312.7029.478

[186] Rastogi T, Reddy KS, Vaz M, Spiegelman D, Prabhakaran D, Willett WC, et al. Diet and risk of ischemic heart disease in India. The American Journal of Clinical Nutrition. 2004;**79**:582-592. DOI: 10.1093/ajcn/79.4.582

[187] Saluk J, Bijak M, Kołodziejczyk-Czepas J, Posmyk M, Janas K, Wachowicz B. Anthocyanins from red cabbage extract—Evidence of protective effects on blood platelets. Open Life Sciences. 2012;**7**:655-663. DOI: 10.2478/s11535-012-0057-9

[188] Manchali S, Murthy KNC, Patil BS. Crucial facts about health benefits of popular cruciferous vegetables. Journal of Functional Foods. 2012;**4**:94-106. DOI: 10.1016/j.jff.2011.08.004

[189] Jeffery EH, Araya M. Physiological effects of broccoli consumption. Phytochemistry Reviews. 2009;**8**:283-298. DOI: 10.1007/s11101-008-9106-4

[190] Murashima M, Watanabe S, Zhuo XG, Uehara M, Kurashige A. Phase 1 study of multiple biomarkers for metabolism and oxidative stress after one-week intake of broccoli sprouts. BioFactors. 2004;**22**:271-275. DOI: 10.1002/biof.5520220154

[191] Jorge PA, Neyra LC, Osaki RM. Effect of eggplant on plasma lipid levels, lipidic peroxidation and reversion of endothelial dysfunction in experimental hypercholesterolemia. Arquivos Brasileiros de Cardiologia. 1998;**70**:87-91

[192] Guimarães PR, Galvão AM, Batista CM, Azevedo GS, Oliveira RD, Lamounier R, et al. Eggplant (*Solanum melongena*) infusion has a modest and transitory effect on hypercholesterolemic subjects. Brazilian Journal of Medical and Biological Research. 2000;**33**:1027-1036

[193] Kwon YI, Apostolidis E, Shetty K. In vitro studies of eggplant (*Solanum melongena*) phenolics as inhibitors of key enzymes relevant for type 2 diabetes and hypertension. Bioresource Technology. 2008;**99**:2981-2988

[194] Anderson JW, Deakins DA, Floore TL, Smith BM, Whitis SE. Dietary fiber

and coronary heart disease. Critical Reviews in Food Science and Nutrition. 1990;**29**:95-147

[195] Menotti A, Kromhout D, Blackburn H, Fidanza F, Buzina R, Nissinen A. Food intake patterns and 25-year mortality from coronary heart disease: Cross-cultural correlations in the seven countries study. European Journal of Epidemiology. 1999;**15**:507-515

[196] Nöthlings U, Schulze MB, Weikert C, Boeing H, Van der Schouw YT, Bamia C, et al. Intake of vegetables, legumes, and fruit, and risk for all-cause, cardiovascular, and cancer mortality in a European diabetic population. The Journal of Nutrition. 2008;**138**:775-781. DOI: 10.1093/jn/138.4.775

[197] Lattimer JM, Haub MD. Effects of dietary fiber and its components on metabolic health. Nutrients. 2010;**2**:1266-1289. DOI: 10.3390/nu2121266

[198] Nicolle C, Cardinault N, Aprikian O, Busserolles J, Grolier P, Rock E, et al. Effect of carrot intake on cholesterol metabolism and on antioxidant status in cholesterol-fed rat. European Journal of Nutrition. 2003;**42**:254-261. DOI: 10.1007/s00394-003-0419-1

[199] Gramenzi A, Gentile A, Fasoli M, Negri E, Parazzini F, La Vecchia C. Association between certain foods and risk of acute myocardial infarction in women. British Medical Journal. 1990;**300**:771-773. DOI: 10.1136/bmj.300.6727.771

[200] Gilani AH, Shaheeri F, Saeed SA, Bibi S, Irfamillah-Sadiq M, Faiz S. Hypotensive action of coumarin glycoside from daucus carot. Phytomedicine. 2000;**7**:423-426. DOI: 10.1016/S0944-7113(00)80064-1

[201] Carter P, Gray LJ, Troughton J, Khunti K, Davies MJ. Fruit and vegetable intake and incidence of type 2 diabetes mellitus: Systematic review and meta-analysis. British Medical Journal. 2010;**341**:c4229. DOI: 10.1136/bmj.c4229

[202] Bazzano LA, Li TY, Joshipura KJ, Hu FB. Intake of fruit, vegetables and fruit juices and risk of diabetes in women. Diabetes Care. 2008;**31**: 1311-1317. DOI: 10.2337/dc08-0080

[203] Khan BA, Abraham A, Leelamma S. Hypoglycemic action of *Murraya koenigii* (curry leaf) and *Brassica juncea* (mustard): Mechanism of action. Indian Journal of Biochemistry and Biophysics. 1995;**32**:106-108

[204] Tundis R, Loizzo MR, Menichini F. Natural products as alpha-amylase and alpha-glucosidase inhibitors and their hypoglycaemic potential in the treatment of diabetes: An update. Mini Reviews in Medicinal Chemistry. 2010;**10**:315-331

[205] Yoshikawa M, Murakami T, Kadoya M, Yamahara J, Matsuda H. Medicinal foodstuff. III. Sugar beet. Hypoglicemic oleanolic acid oligoglycosides, betavulgarosides I, II, III, and IV, from the root of *Beta vulgaris* L. (*Chenopodiaceae*). Chemical and Pharmaceutical Bulletin. 1996;**44**:1212-1217

[206] American Diabetes Association (ADA). Standards of Care. Diabetes Care, 2016;**39**:S1-S119

[207] Gu JF, Zheng ZY, Yuan JR, Zhao BJ, Wang CF, Zhang L, et al. Comparison on hypoglycemic and antioxidant activities of the fresh and dried *Portulaca oleracea* L. in insulin-resistant HepG2 cells and streptozotocin-induced C57BL/6J diabetic mice. Journal of Ethnopharmacology. 2015;**161**:214-223. DOI: 10.1016/j.jep.2014.12.002

[208] Wainstein J, Landau Z, Dayan YB, Jakubowicz D, Grothe T, Perrinjaquet-Moccetti T, et al. Purslane extract and glucose homeostasis in adults

with type 2 diabetes: A double-blind, placebo-controlled clinical trial of efficacy and safety. Journal of Medicinal Food. 2016;**19**:133-140. DOI: 10.1089/jmf.2015.0090

[209] Swamy KRM, Nath P, Ahuja KG. Vegetables for human nutrition and health. In: Nath P, editor. The Basics of Human Civilization-Food, Agriculture and Humanity, Volume-II-Food. New Delhi, India: Prem Nath Agricultural Science Foundation (PNASF), Bangalore & New India Publishing Agency (NIPA); 2013. pp. 145-198

[210] El-Demerdash FM, Yousef MI, El-Naga NA. Biochemical study on the hypoglycemic effects of onion and garlic in alloxan-induced diabetic rats. Food and Chemical Toxicology. 2005;**43**: 57-63. DOI: 10.1016/j.fct.2004.08.012

[211] Ogunmodede OS, Saalu LC, Ogunlade B, Akunna GG, Oyewopo AO. An evaluation of the hypoglycemic, antioxidant and hepatoprotective potentials of onion (*Allium cepa* L.) on alloxan-induced diabetic rabbits. International Journal of Pharmacology. 2012;**8**:21-29. DOI: 10.3923/ijp.2012.21.29

[212] Yoshinari O, Shiojima Y, Igarashi K. Anti-obesity effects of onion extract in Zucker diabetic fatty rats. Nutrients. 2012;**4**:1518-1526. DOI: 10.3390/nu4101518

[213] Wang H, Kruszewki A, Brautigan DL. Cellular chromium activation of insulin receptor kinase. Biochemistry. 2005;**44**:8167-8175. DOI: 10.1021/bi0473152

[214] Chau CF, Chen CH, Lee MH. Comparison of the characteristics, functional properties, and in vitro hypoglycemic effects of various carrot insoluble fiber-rich fractions. Lebensmittel-Wissenshaff und Technologie. 2004;**37**:155-160. DOI: 10.1016/j.lwt.2003.08.001

[215] Coyne T, Ibiebele TI, Baade PD. Diabetes mellitus and serum carotenoids: Findings of a population-based study in Queensland, Australia. The American Journal of Clinical Nutrition. 2005;**82**:685-693

[216] Chen Q, Chan LLY, Li ETS. Bitter melon (*Momordica charantia*) reduces adiposity, lowers serum insulin and normalizes glucose tolerance in rats fed a high fat diet. The Journal of Nutrition. 2003;**133**:1088-1093

[217] Patil B, Jayaprakasha GK, Vikram A. Indigenous crops of Asia and Southeast Asia: Exploring health-promoting properties. Hortscience. 2012;**47**:821-827

[218] Chao PM. One more support for recruiting bitter melon in therapeutic diet for diabetes and its comorbidity management—Bitter melon ameliorates hepatic steatosis related with hyperglycemia. BIT's 4th Annual World Congress of Diabetes–2015, Kaohsiung, Taiwania 2015; p. 236

[219] Ahmad N, Hassan M, Halder H, Bennoor K. Effect of *Momordica charantia* (Karolla) extracts on fasting and postprandial serum glucose levels in NIDDM patients. Bangladesh Medical Research Council Bulletin. 1999;**25**:11

[220] Yeh G, Eisenberg D, Kaptchuk T, Phillips R. Systematic review of herbs and dietary supplements for glycemic control in diabetes. Diabetes Care. 2003;**26**:1277. DOI: 10.2337/diacare.26.4.1277

[221] Chen J, Tian R, Qiu M, Lu L, Zheng Y, Zhang Z. Trinorcucurbitane and cucurbitane triterpenoids from the roots of *Momordica charantia*. Phytochemistry. 2008;**69**:1043-1048. DOI: 10.1016/j.phytochem.2007.10.020

[222] Saxena A, Vikram N. Role of selected Indian plants in management of type 2 diabetes: A review. The Journal

of Alternative and Complementary Medicine. 2004;**10**:369-378. DOI: 10.1089/107555304323062365

[223] Singh LW. Traditional medicinal plants of Manipur as anti-diabetics. Journal of Medicinal Plant Research. 2011;**5**:677-687

[224] Villegas R, Gao YT, Yang G, Li HL, Elasy TA, Zheng W, et al. Legume and soy food intake and the incidence of type 2 diabetes in the Shanghai women's health study. The American Journal of Clinical Nutrition, 2008;**87**:162-167. DOI: 10.1093/ajcn/87.1.162